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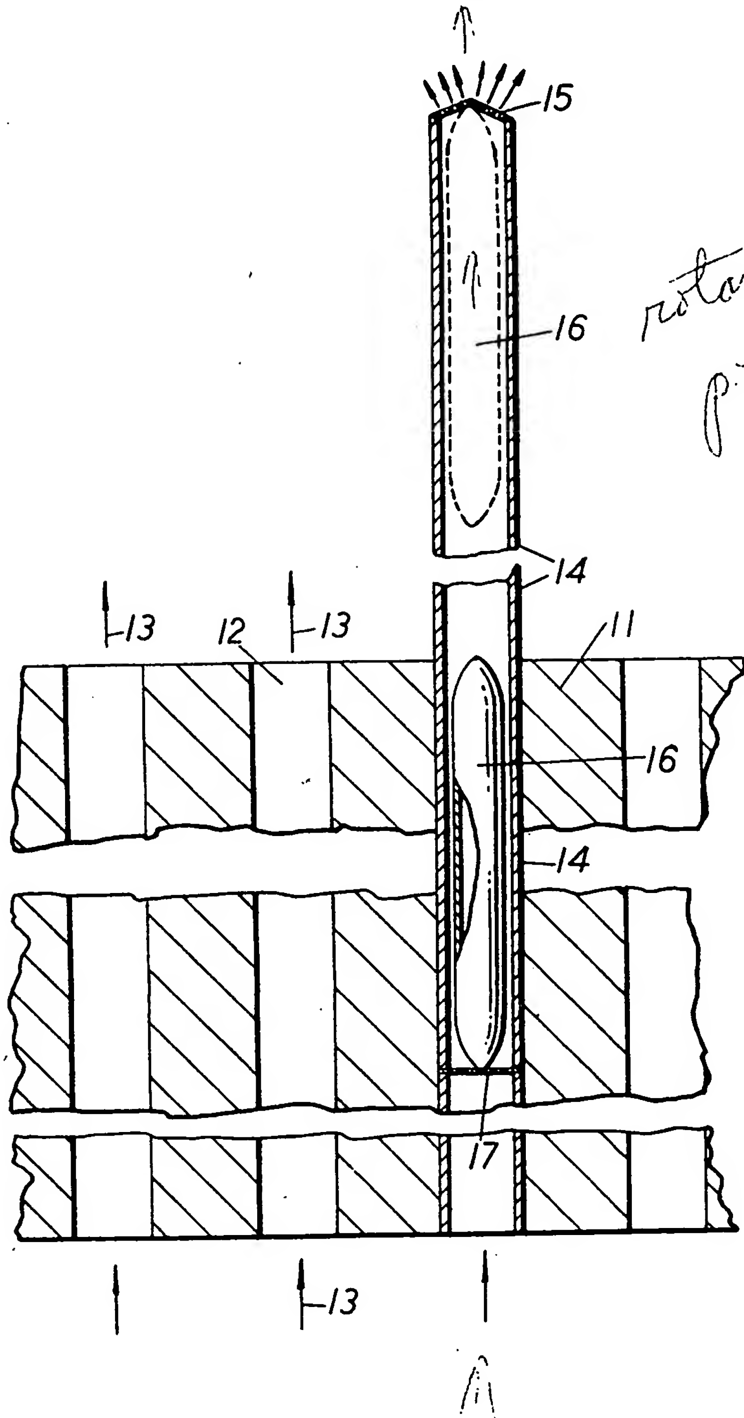
[redacted]

969,089 PROVISIONAL SPECIFICATION

1 SHEET

This drawing is a reproduction of the Original on a reduced scale.



rotameter principle

PATENT SPECIFICATION

DRAWINGS ATTACHED

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Index at acceptance: —G6 C(1A, 1C, 2A2B, 2A5, 2D1J, 2DX)

International Classification: —G 21

COMPLETE SPECIFICATION

Nuclear Reactor Safety Rod

We, UNITED KINGDOM ATOMIC ENERGY AUTHORITY, London; a British Authority, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement: —

This invention relates to nuclear reactor safety rods.

The reactivity of a nuclear reactor is conventionally controlled by control rods which are moved into and out of the core of the reactor; these rods may be of fissile material or neutron-absorbing material. Certain of these rods are usually designated safety rods and provide a safety system which serves to shut down the reactor in the event of an emergency, for example a failure in the circulation of coolant through the core. Safety rods must be capable of moving very rapidly and their reactivity equivalent, a measure of the reactivity the rods can control, must be appreciably greater than the maximum excess reactivity built into the reactor. One well-known method of ensuring movement of safety rods to their shut-down position is to hold the rods above this position by means of a latch which is tripped in the event of an emergency to allow the rods to fall to their shut-down position. In some reactors movement of safety rods is assisted hydraulically or by springs.

According to the present invention, a nuclear reactor having a core and a circuit for circulation of fluid coolant through the core is provided with a guide tube connected into the coolant circuit and having a part penetrating the core, and with a reactivity controlling body immersed in coolant within the guide tube which is biassed towards a reference position in which the reactivity of the core is reduced but which is supportable, against the bias, by flow of coolant through the guide tube, in a position of less reducing effect on the core reactivity.

In one application the reactivity controlling body is a safety rod which is biassed towards a reactor shut-down position and is supportable, against the bias, in an operational position by coolant flow in the guide tube resulting from operational flow of coolant in the coolant circuit.

On embodiment of the invention will now be described by way of example with reference to the diagrammatic drawing accompanying the provisional specification which shows part of the core of a reactor fitted with a safety rod.

The reactor of this example is a heterogeneous, gas-cooled, graphite-moderator reactor. A graphite core structure 11 has upright fuel channels 12 in which fuel elements (not shown) of fissile material are stacked. A gaseous coolant (arrow 13), for example helium, is circulated through a coolant circuit and sweeps up the fuel channels abstracting heat from the fuel elements to yield the heat subsequently to a heat exchanger (not shown).

Extending through the core structure and upwardly above this structure, parallel to the fuel channels, is a guide tube 14 (several such tubes may be provided in one reactor). The lower end of the guide tube is open whilst the upper end is closed by a grid which has apertues 15. The lower end of the guide tube is placed in communication with incoming coolant in the coolant circuit so that a by-pass stream of coolant flows up the guide tube and bleeds through the apertues 15 to rejoin the main stream of coolant which has swept the fuel channels.

Within the guide tube is a reactivity controlling body in the form of a safety-rod 16 constituted by a closed, hollow, thin-walled

[*Price 4s. 6d.*]

cylinder of neutron-absorbing material (where a reactor has several guide tubes there would be one safety rod in each tube). The safety rod is a stream-lined shape and is immersed in coolant within the guide tube being free to move between a lower reference position (full lines), in which it is positioned within the core resting upon a grid 17, and an upper operational position (broken lines) in which it is situated outside the core.

The safety rod is biassed by gravity to its lower reference position in which its neutron-absorbing character acts to reduce the reactivity of the reactor; accordingly this position is appropriate to reactor shut-down. When the reactor is brought into operation, circulation of the coolant in the coolant circuit is commenced with the result that the safety rod is lifted by the resultant flow of coolant through the guide tube which subjects the rod to a viscous drag. On the reactor achieving normal coolant flow at operational pressure, the safety rod is held in its upper operational position in which its neutron-absorbing character has little effect on the reactivity of the reactor. While the safety rod is in its operational position, it remains immersed in coolant which flows through its guide tube and this coolant flow sweeps the apertures 15 keeping them free. Minor oscillations in the coolant flow do not cause the safety rod to move sufficiently to affect the reactivity of the reactor.

Should there be a failure in the circulation of the coolant, for example due to some electrical failure, the reduction of coolant flow would permit the safety rod to fall in the guide tube until, in the absence of coolant flow, it rests in its shut-down position.

The safety rod is replaceable and need not have a long irradiation life. The rod does not suffer much absorption depletion by neutron capture while it is in its operational position.

In a reactor fitted with safety rods embodying the invention, it is desirable that other control rods have an overriding reactivity equivalent so that levitation of the safety rods could not in itself render the reactor critical.

It is to be understood that the invention is not limited by the details of the foregoing example; for instance although the safety system has been described with reference to a gas-cooled, graphite-moderated reactor, it is equally applicable to reactors in which the coolant is water or a liquid metal.

Our Patent No. 907394 is directed to a nuclear reactor having a core in which reactivity controlling bodies are biassed towards a position in which the core is rendered non-critical and are held against the bias in positions in which the core is rendered critical by means powered by the flow of reactor coolant.

WHAT WE CLAIM IS:—

1. A nuclear reactor having a core and a circuit for circulation of fluid coolant through the core wherein a guide tube connected into the coolant circuit has a part penetrating the core and wherein a reactivity controlling body immersed in coolant within the guide tube is biassed towards a reference position in which the reactivity of the core is reduced but is supportable, against the bias, by flow of coolant through the guide tube in a position of less reducing effect on the core reactivity.

2. A nuclear reactor as claimed in claim 1 wherein the reactivity controlling body is a safety rod which is biassed towards a reactor shut-down position and is supportable, against the bias, in an operational position by coolant flow in the guide tube resulting from operational flow of coolant in the coolant circuit.

3. A nuclear reactor as claimed in claim 1 or claim 2 wherein the guide tube is upright and the reactivity controlling body is biassed towards its reference position by gravity.

4. A nuclear reactor as claimed in claim 3 where one grid supports the reactivity controlling body in its reference position and a second grid limits movement of the body away from its reference position.

5. A nuclear reactor as claimed in any one of the preceding claims wherein the reactivity controlling body is of neutron-absorbing material.

6. A nuclear reactor equipped with a reactivity controlling unit substantially as hereinbefore described with reference to and illustrated in the drawing accompanying the provisional specification.

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3,123,532 CROSS REFERENCE EXAMINER

March 3, 1964 J. W. MICHEL 3,123,532

CONTROL ROD POSITIONED BY FLUID FLOW THROUGH THE ROD CHANNEL

Filed May 6, 1963 2 Sheets-Sheet 1

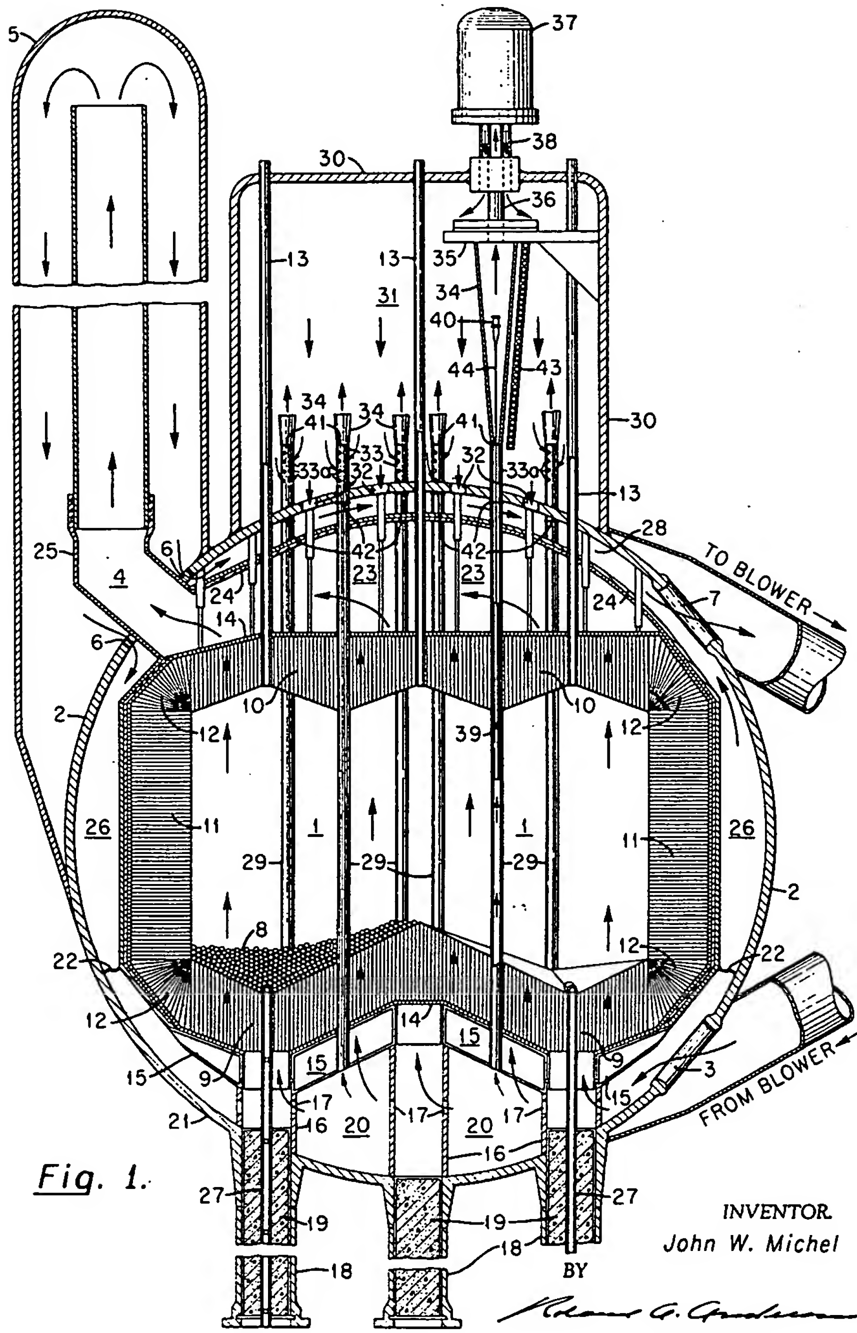

Fig. 1.

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CONTROL ROD POSITIONED BY FLUID FLOW THROUGH THE ROD CHANNEL

Filed May 6, 1963 2 Sheets-Sheet 2

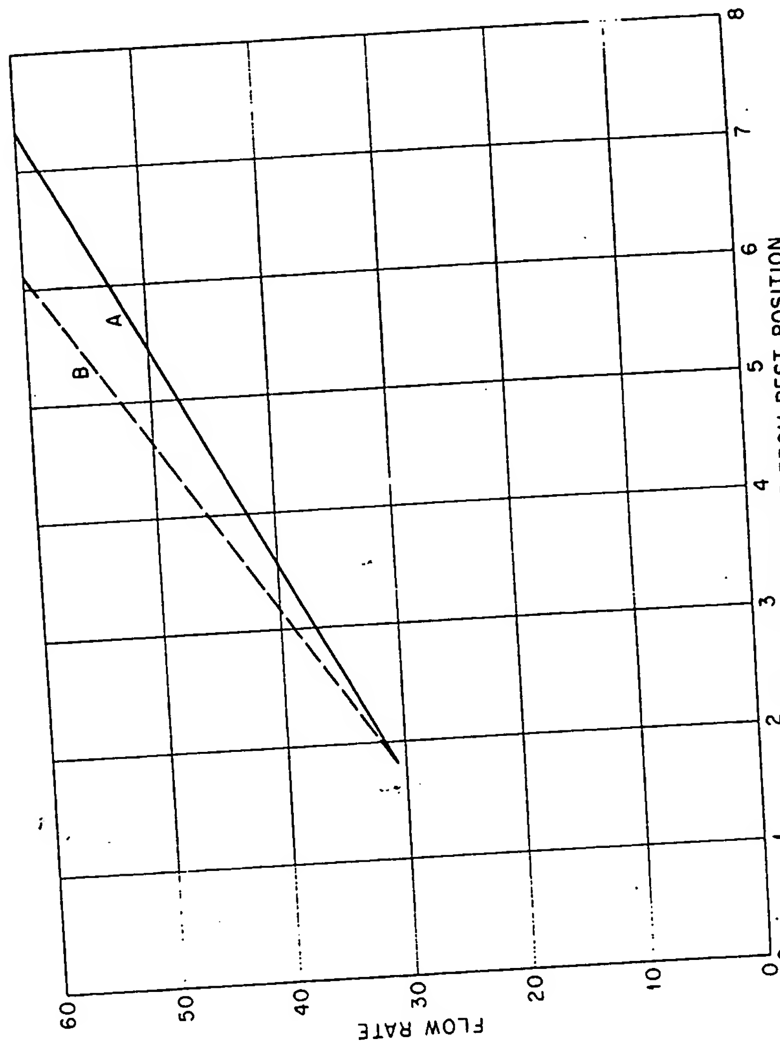

Fig. 2.

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3,123,532

Patented Mar. 3, 1964

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3,123,532

CONTROL ROD POSITIONED BY FLUID FLOW THROUGH THE ROD CHANNEL

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Filed May 5, 1963, Ser. No. 278,500
5 Claims. (Cl. 176—36)

This invention relates generally to neutronic reactors and more particularly to a control rod drive system for use in neutronic reactors.

Characteristic of most neutronic reactors is the use of neutron absorbing control rods to regulate and control the neutron chain reaction contained therein. The control rods are generally disposed to move vertically into and out of the reactor core and are moved through the use of electro-mechanical drive units with direct mechanical linkages. Electro-mechanical units, however, are inherently complex and costly and require considerable space. The complex nature of such control rod drive units decreases their reliability and increases the time and expense required for maintenance operations. Inasmuch as reactor operation is highly dependent upon the proper functioning of its control rods, the safety and economy of operation of reactors which utilize complex electro-mechanical control rod drive systems is reduced. The cost and space requirements of electro-mechanical drive units restrict the number and spacing of control rods which can be used in a single reactor. Use of a limited number of widely spaced control rods gives rise to undesirable perturbations in the neutron flux distribution, and forces a higher degree of reliability on each control rod.

A further undesirable limitation of electro-mechanical drive systems is their inability to operate in very high temperature or radiation environments. This operating limitation necessitates the isolation of control rod drives from the high temperature and radiation zones characteristic of most reactors.

It is, therefore, a general object of this invention to provide a control rod drive system of simplified design.

Another object of this invention is to provide a control rod drive system having inherent safety features.

Another object of this invention is to provide a control rod drive system which will permit the use of closely spaced control rod channels.

Still another object of this invention is to provide a control rod drive system capable of operation in a high temperature environment.

A further object of this invention is to provide a control rod drive system capable of operation in an intense radiation environment.

Other objects of this invention will be apparent from an examination of the following description of the invention and the appended drawings, wherein:

FIG. 1 is an illustration of a gas cooled reactor utilizing an embodiment of the subject control rod drive system, and

FIG. 2 is a graph illustrating the performance characteristics of control rod drives constructed according to the subject invention.

In accordance with the principles of the present invention, the above objects are attained by a control rod drive system comprising an outwardly tapered tube member

2

coaxially mounted atop each control rod channel, fluid inlet means at the bottom of the tapered tube member, fluid pumping means of variable capacity adapted to pump fluid upwardly through the outwardly tapering tube member, a float member disposed within the tapered tube member and adapted to change its vertical position in response to variations in the fluid flow rate through the tapered tube member, connecting means communicating between the float member and the corresponding control rod, and float position indicating means adapted to indicate the vertical position of the float member, thereby indicating the corresponding control rod position.

To illustrate the invention in greater detail, reference is made to the drawings, initially to FIG. 1, which is a vertical cross sectional view of the reactor disclosed in an application of common assignee, Serial No. 107,603, filed May 3, 1961, now U.S. Patent No. 3,100,187, adapted to use applicant's control rod system. A substantially cylindrical reactor core 1 is enclosed by a spherical pressure shell 2 which is provided with a cool-gas inlet 3 from a blower (not shown), a hot-gas outlet 4 to a load such as the schematically illustrated steam generator 5, a concentric cool-gas return inlet 6, and a cool-gas return outlet 7 to the low pressure side of the blower. Core 1 is made up of a multiplicity of small diameter graphite spheres containing a fissionable material such as U^{235}, a portion of which are indicated by reference numeral 8. A lower reflector 9, an upper reflector 10, an annular side reflector 11, and wedge shaped annular corner reflectors 12 define the outer limits of the core, lower reflector 9 serving additionally as a support for fuel spheres 8. Graphite fuel spheres 8 are loaded into the core through a plurality of loading tubes 13 penetrating the upper reflector 10 and are removed through outlet tubes 27 which penetrate through the lower reflector 9.

Lower reflector 9 is secured to a steel reflector grid 14. Grid 14 is in turn supported by a grid 15 which is carried by pressure-vessel-supported tubes 16. Apertures 17 in tubes 16 are provided so as to enable coolant gas flow to the core regions above the interiors of the tubes. The interior of each supporting tube 16 communicates with the interior of an associated access tube 18, which is provided with a removable shield plug 19.

When the reactor is in operation, an exteriorly located blower delivers a gaseous coolant through inlet 3 into an inlet plenum 20 which is defined by bottom reflector 9, the lower portion 21 of pressure vessel 2, and an annular baffle 22. The inlet gas stream is directed upwardly through bottom reflector 9, core 1, and top reflector 10 as is indicated by the arrows. After traversing top reflector 10, the gas enters a hot-gas plenum 23, which is defined by a thermally insulated baffle 24, and is directed thereby to steam generator 5 through outlet 25. After being cooled in steam generator 5, the gas is returned to the interior of the reactor through concentric inlet 6. The thus-returned cool gas flows through the space 26 around the periphery of the side reflector 11, and over the top of the hot-gas plenum 24 through space 28 to outlet 7 which communicates with the low pressure side of the blower.

Applicant's control rod system is shown in FIG. 1 in an embodiment suitable for use with the above-described reactor concept. A multiplicity of tubes 29 made of low nuclear cross section material penetrate pressure vessel 2, insulated baffle 24, upper reflector 10, core 1 and